

DESCRIPTION

(as originally filed)

PROCESS AND APPARATUS FOR GRINDING WORK FORNON-CIRCULAR ROTOR, AS WELL AS CAMSHAFT

5 FIELD OF THE INVENTION

The present invention relates to an improvement in a process for grinding a work for a non-circular rotor for grinding an outer peripheral surface of the work by a rotary grindstone advanced and retreated by an NC control depending on the profile
10 of the work, while rotating the work for the non-circular rotor about an axis thereof, and also relates to an apparatus for grinding a work for a non-circular rotor, comprising a work-rotating means for rotating the work for the non-circular rotor about the axis, while supporting the work, a rotary
15 grindstone capable of grinding an outer peripheral surface of the work, grindstone-rotating and reciprocally moving means capable of being advanced and retreated with respect to the outer peripheral surface of the work, while driving the rotary grindstone in rotation, a standard phase-indexing means for
20 indexing a standard phase of the work, and an NC control unit for advancing and retreating the rotary grindstone to grind the outer peripheral surface of the work based on the standard phase of the work indexed by the standard phase-indexing means and previously input data for the profile of the work. Further,
25 the present invention relates to an improvement in a camshaft fabricated by the above-described process.

BACKGROUND ART

Such process and apparatus for grinding a non-circular rotor work are already known, for example, as disclosed in patent document 1.

5 [Patent Document 1]

Japanese Patent Application Laid-open No.9-300193

In such non-circular rotor work grinding process and apparatus, it is required that the standard phase of the work be first indexed, when the outer peripheral surface of the work
10 for the non-circular rotor is to be ground. Therefore, it is a conventional practice that a recess for indicating the standard phase is formed in advance in the outer peripheral surface during the formation of the work, and a movable element of a standard phase sensor placed at a given point at the grinding is fitted
15 into the recess, whereby the standard phase of the work is indexed.

However, to fit the movable element of the standard phase sensor into the recess, a fitting clearance must be provided between the recess and the sensor and is one cause of a reduction in accuracy of indexing of the standard phase of the work. The
20 reduction in indexing accuracy compels an increase in grinding margin of the work and as a result, it is difficult to shorten the grinding time.

DISCLOSURE OF THE INVENTION

Accordingly, the present invention has been accomplished
25 in view of the above circumstances, and it is an object of the present invention to provide non-circular rotor work-grinding

process and apparatus of the above-described type, wherein even if a special recess is not formed in an outer periphery of a work for a non-circular rotor, the indexing of the standard phase of the work can be achieved properly, thereby enabling a reduction in grinding margin of the work, thus, the shortening of the grinding time, and to provide a camshaft which has a good appearance and which is formed from a camshaft blank whose fabrication is simplified.

To achieve the above object, according to a first aspect and feature of the present invention, there is provided a process for grinding a work for a non-circular rotor for grinding an outer peripheral surface of the work by a rotary grindstone advanced and retreated by an NC control depending on the profile of the work, while rotating the work for the non-circular rotor about an axis thereof, characterized in that the following steps are carried out: a first step of detecting a predetermined lift amount of the outer peripheral surface of the work at a given point to index a standard phase of the work, and a second step of advancing or retreating the rotary grindstone by the NC control based on the standard phase of the work indexed at the first step to grind the outer peripheral surface of the work.

With the first feature, even if a special recess is not formed in the outer periphery of the work for the non-circular rotor, the indexing of the standard phase of the work can be achieved properly, thereby providing a reduction in grinding margin of the work, thus, the shortening of the grinding time.

According to a second aspect and feature of the present invention, in addition to the first feature, the work includes a base circle portion having a constant curvature radius, and a cam lobe leading to circumferential opposite ends of the base circle portion, and the predetermined lift amount between the
5 base circle portion and the cam lobe is detected at the first step.

With the second feature, the predetermined lift amount can be detected properly from the base circle portion to the
10 cam lobe of the work, and the indexing of the standard phase of the work can be achieved more precisely.

According to a third aspect and feature of the present invention, there is provided an apparatus for grinding a work for a non-circular rotor, comprising a work-rotating means for
15 rotating the work for the non-circular rotor about an axis thereof, while supporting the work, a rotary grindstone capable of grinding an outer peripheral surface of the work, grindstone-rotating and reciprocally moving means capable of being advanced and retreated with respect to the outer peripheral
20 surface of the work, while driving the rotary grindstone in rotation, a standard phase-indexing means for indexing a standard phase of the work, and an NC control unit for advancing and retreating the rotary grindstone to grind the outer peripheral
25 surface of the work based on the standard phase of the work indexed by the standard phase-indexing means and previously input data for the profile of the work, characterized in that the standard

phase-indexing means comprises a standard phase sensor for detecting a predetermined lift amount of the outer peripheral surface of the work at a given point.

5 The work-rotating means corresponds to a first electric motor 8 in each of embodiments of the present invention, which will be described hereinafter, and the grindstone-rotating and reciprocally moving means corresponds to a third electric motor 18 and a movable table-driving means 12.

10 With the third feature, even if a special recess is not formed in the outer periphery of the work, the indexing of the standard phase of the work can be achieved properly by the standard phase sensor, thereby providing a reduction in grinding margin of the work, thus, the shortening of the grinding time.

15 According to a fourth aspect and feature of the present invention, in addition to the third feature, the work includes a base circle portion having a constant curvature radius, and a cam lobe leading to circumferential opposite ends of the base circle portion, and the sensor is formed to detect the predetermined lift amount between the base circle portion and
20 the cam lobe.

With the fourth feature, the predetermined lift amount can be detected properly from the base circle portion to the cam lobe of the work by the standard phase sensor, and the indexing of the standard phase of the work can be achieved more precisely.

25 According to a fifth aspect and feature of the present invention, there is provided a camshaft which includes cams each

comprising a base circle portion ground by the grinding process according to the first or second feature, and a cam lobe leading to circumferential opposite ends of the base circle portion, the camshaft having no recess indicating a standard phase in
5 an outer peripheral surface thereof.

With the fifth feature, when a blank for the camshaft is to be fabricated, it is unnecessary to form a recess indicating the standard phase in an outer peripheral surface of the blank. Thus, the fabrication of the blank can be simplified, and a good
10 appearance of the camshaft can be provided.

The above and other objects, features and advantages of the invention will become apparent from the following description of the preferred embodiments taken in conjunction with the accompanying drawings.

15 BRIEF DESCRIPTION OF THE DRAWINGS

Fig.1 is a front view of a camshaft-grinding apparatus according to embodiments of the present invention; Fig.2 is an enlarged sectional view taken along a line 2-2 in Fig.1; Fig.3 is a sectional view taken along a line 3-3 in Fig.2; Fig.4 is
20 a sectional view taken along a line 4-4 in Fig.3 (showing a cam whose standard phase is being detected); Fig.5 is an enlarged view of a portion indicated by an arrow 5 in Fig.1 (showing a rotary grindstone which is being dressed); Fig.6 is a view similar to Fig.3, but showing a work which is being ground; Fig.7 is
25 a sectional view taken along a line 7-7 in Fig.6; and Fig.8 is a view similar to Fig.4, but showing a modification of a deflashing

brush.

BEST MODE FOR CARRYING OUT THE INVENTION

The present invention will now be described by way of preferred embodiments with reference to the accompanying
5 drawings.

Referring first to Figs.1 and 2, an X-direction rail 3 is formed on a table 2 on a machine base 1 placed on a floor G to extend in an X-direction, and a Y-direction rail 4 is formed on an upper surface of the machine base 1 to extend in a Y-direction
10 perpendicular to the X-direction. A head stock 5 and a tail stock 6 are mounted on the X-direction rail 3, so that they can be moved toward and away from each other. A main spindle 7 is carried in the head stock 5, and a first electric motor 8 for rotating the main spindle 7 is mounted to the head stock 5 and
15 connected to an outer end of the main spindle 7. A chuck 9 is mounted to an inner end of the main spindle 7.

The table 2 is provided with a tail stock 19 for supporting a work 10 for a non-circular rotor by cooperation with the chuck 9 of the head stock 5. The work 10 for the non-circular rotor
20 is a valve-operating camshaft in a multi-cylinder engine, in the case of the illustrated example, and includes a plurality of cams 10a, 10b ---- 10n which are arranged at predetermined distances in an axial direction, and each of which comprises a base circle portion 50 having a constant curvature radius,
25 and a cam lobe 51 leading to circumferential opposite ends of the base circle portion 50 (see Fig.4). The cams 10a, 10b ---

10n are different in phases from one another. The camshaft 10 is formed by a precision casting, and outer peripheral surfaces of the plurality of cams 10a, 10b --- 10n are to be ground.

A movable table 11 is slidably mounted on the Y-direction rail 4, and a movable table-driving means 12 capable of reciprocally move the movable table 11 along the Y-direction rail 4 is mounted between the table 2 and the movable table 11. The movable table-driving means 12 is comprised of a screw shaft 13 disposed in the Y-direction and threadedly engaged with the movable table 11, and a second electric motor 14 mounted to the table 2 and capable of rotating the screw shaft 13 in opposite directions.

An upper surface rail 15 and a side rail 16 are formed on an upper surface and a side of the movable table 11 to extend in the X-direction, and a third electric motor 18 is mounted with its output shaft 18a turned in the X-direction on a motor base 17 which is slidably mounted on the upper surface rail 15. A wheel spindle 21 is carried with its axis turned in the X-direction on a wheel spindle stock 20 which is slidably mounted on the side rail 16, and a rotary grindstone 22 for grinding the outer peripheral surfaces of the cams 10a, 10b --- 10n of the camshaft 10 sequentially is detachably secured to the wheel spindle 21 by a plurality of bolts 23, 23 (see Fig.3).

The output shaft 18a of the third electric motor 18 and the wheel spindle 21 are connected to each other by a driving pulley 24 and a driven pulley 25 fixedly mounted on the output

shaft 18a and the wheel spindle 21 respectively and by a belt 26 wound around the pulleys 24 and 25, so that the third electric motor 18 drives the wheel spindle 21 in rotation by its output.

The motor base 17 and the wheel spindle stock 20 are
5 integrally connected to each other by a connecting block 28,
so that they can be slid simultaneously on the upper surface
rail 15 and the side rail 16. A connecting block-driving means
29 capable of reciprocally moving the connecting block 28 along
the upper surface rail 15 and the side rail 16 is mounted between
10 the connecting block 28 and the movable table 11. The connecting
block-driving means 29 is comprised of a screw shaft 30 disposed
in the X-direction and threadedly engaged with the connecting
block 28, and a fourth electric motor 31 mounted to the movable
table 11 and capable of rotating the screw shaft 30 in opposite
15 directions.

An NC control unit 33 is mounted on the machine base 1.
Inputted to the NC control unit 33 are a detection signal from
a camshaft rotated-position sensor 34 mounted on the first
electric motor 8 for indexing the rotated position of the camshaft
20 10 from the rotated position of the main spindle 7, and a detection
signal from a standard phase sensor 35 for indexing the standard
phase of the cam 10a in a predetermined position (the outermost
cam 10a closest to the head stock 5 in the illustrated example),
in addition to profile data P of the cams 10a, 10b --- 10n on
25 the camshaft 10, data E of phase difference between the cams
10a, 10b --- 10n as well as data S of axial distances between

the cams 10a, 10b --- 10n. The NC control unit controls the operations of the first to fourth electric motors 8, 14, 18 and 31 based on these signal and data.

The standard phase sensor 35 is mounted at a tip end of
 5 a sensor-supporting arm 37 pivotally supported on the wheel spindle stock 20. The sensor-mounting arm 37 is capable of being swung between a detecting position A in which the standard phase sensor 35 is opposed to the outer peripheral surface of the outermost cam 10a closest to the headstock 5 and a resting position
 10 B in which the sensor 35 is spaced apart from the camshaft 10. An electromagnetic or electric actuator 38 is connected to the sensor-supporting arm 37 for swinging the sensor-supporting arm 37 between the two positions A and B.

When the cam 10a has been rotated from the base circle
 15 portion 50 toward the cam lobe 51 relative to the standard phase sensor 35, the standard phase sensor 35 detects a predetermined lift amount of the cam 10a between the base circle portion 50 and the cam lobe 51, and the detection signal of the standard phase sensor 35 is input as a signal indicative of the standard
 20 phase of the cam 10a to the NC control unit 33. The type of standard phase sensor 35, which can be used, may be any of a non-contact type and a contact type.

As shown in Figs. 3 and 4, a deflashing brush 40 is mounted to the wheel spindle 21 adjacent the rotary grindstone 22. The
 25 deflashing brush 40 is comprised of an annular brush body 41, a large number of metal wires 42, 42 as brush element wires embedded

in the brush body 41, and a pair of wire-protecting plates 43, 43 opposed to opposite sides of the wires 42, 42, while clamping the brush body 41 therebetween. The brush body 41 and the wire-protecting plates 43, 43 are secured to the wheel spindle 21
5 along with the rotary grindstone 22 by the bolts 23, 23.

To embed the wires 42, 42, a large number of through-bores 44, 44 are made axially in a plurality of rows in the brush body 41 and arranged circumferentially of the brush body 41, and two tip ends of the wires 42, 42 each folded into two at the central
10 portion are inserted through the every two circumferentially or axially adjacent through-bores 44, 44 from the side of the inner periphery of the brush body 41, and each of the wires 42 is adhesively bonded or brazed in each of the through-bores 44. Each of the wires 42 extends radially outwards from the brush
15 body 41 and has a \wedge -shape bent portion 42a. When the wheel spindle 21 is in a stopped state or in a low-speed rotational state in which it is being rotated at a low speed lower than a usual grinding rotational speed, the tip end of each wire 42 is positioned at a location radially inside the outer peripheral surface of the
20 rotary grindstone 22, but when the rotational speed of the wheel spindle 21 is increased to near the usual grinding rotational speed, the bent portion 42a is stretched by a centrifugal force, so that the tip end of the wire is allowed to protrude radially outwards from the outer peripheral surface of the rotary
25 grindstone 22 (see Figs. 6 and 7). In this way, the deflashing

brush 40 is formed into a variable-diameter type in which its outside diameter, i.e., the outside diameter of the group of the wires 42, 42 can be decreased to smaller, or increased to larger than the outside diameter of the rotary grindstone 22.

5 Each of the wires 42 may be formed in a zigzag shape with a plurality of \wedge -shape bent portions 42a arranged in a line.

As shown in Figs.1 and 5, a dressing motor 45 is mounted to a side of the head stock 5 closer to the movable table 11 with its output shaft 45a parallel to the main spindle 7, and
10 a diamond dresser 46 capable of dressing the rotary grindstone 22 is mounted to the output shaft 45a.

The operation of the first embodiment will be described below.

First, to carry out the dressing of the rotary grindstone
15 22, the outer peripheral surface of the rotary grindstone 22 rotated along with the wheel spindle 21 is brought into contact with the diamond dresser 46 and fed axially, while rotating the wheel spindle 21 at a low speed by the operation of the third electric motor 18 in a state in which the diamond dresser 46
20 is being rotated at a high speed by the operation of the dressing motor 45, as shown in Fig.5.

During such dressing of the rotary grindstone 22, the rotational speed of the wheel spindle 21 is relatively low and hence, each of the wires 42 of the deflashing brush 40 is in
25 contracted state and thus, the diameter of the deflashing brush

40 is smaller than that of the rotary grindstone 22. Therefore, it is possible to avoid the interference of the deflashing brush 40 with the diamond dresser 46.

Now, to grind the outer peripheral surfaces of the plurality of cams 10a, 10b --- 10n of the camshaft 10 formed by the precision casting, first of all, the opposite ends of the camshaft 10 are supported by the chuck 9 of the head stock 5 and the tail stock 19. Then, the sensor-supporting arm 37 is retained in the detecting position A, and the standard phase sensor 35 is opposed to the outer peripheral surface of the outermost cam 10a closest to the head stock 5 (see Fig.4). The camshaft 10 is rotated at a very low speed through the chuck 9 by the first electric motor 8 on the head stock 5. When the base circle portion 50 and the cam lobe 51 of the cam 10a are moved past before a detecting portion of the standard phase sensor 35 in response to the rotation of the camshaft 10, the standard phase sensor 35 detects the predetermined lift amount of the cam 10a, and the detection signal is input as the standard phase signal to the NC control unit 33. Thereafter, the sensor-supporting arm 37 is turned immediately to the resting position B by the actuator 38 to move the standard phase sensor 35 away from the cam 10a. Thus, it is possible to avoid that the standard phase sensor 35 is exposed to a scattered grinding liquid.

When the standard phase signal is input to the NC control unit 33 from the standard phase sensor 35, the NC control unit

33 controls the operations of the first to fourth electric motors 8, 14, 18 and 31 based on the signal input from the camshaft rotated-position sensor 34 and the data P, E and S previously input thereto to reciprocally move the movable table 11 in the Y-direction and feed it at the very low speed in the X-direction while rotating the rotary grindstone 22 at a predetermined grinding rotational speed, whereby the outer peripheral surface of the cam 10a is ground from one end to the other end by the rotary grindstone 22.

During such grinding, the deflashing brush 40 rotated at the relatively high speed along with the rotary grindstone 22 has a diameter increased to larger than that of the rotary grindstone 22 by stretching of the bent portion 42a of each of the wires 42 due to a centrifugal force, as shown in Figs. 6 and 7. Therefore, the deflashing brush 40 brushes the outer peripheral surface of the cam 10a immediately after being ground by the rotary grindstone 22 from one of its end edges toward other end edge. Thus, a ground flash remaining at an end edge of the cam 10a can be removed and at the same time, the ground surface of the cam 10a can be cleaned.

If the grinding and the deflashing of the one cam 10a are finished in the above-described manner, the NC control unit 33 actuates the fourth electric motor 31 to shift the connecting block 28 over only the distance between the adjacent cams 10a, 10b --- 10n in the X-direction, whereby the next cams 10b --- 10n are ground and deflashed sequentially and simultaneously

in a similar manner by the rotary grindstone 22 and the deflashing brush 40.

Since the predetermined lift amount between the base circle portion 50 and the cam lobe 51 of the cam 10a is detected by the standard phase sensor 35, whereby the standard phase of the cam 10a is indexed, as described above, the indexing of the standard phase of the cam 10a can be performed properly even if a special recess is not formed around the outer periphery of the camshaft 10, thereby providing a decrease in grinding margin of the cam 10a, 10b --- 10n, thus, a shortening of grinding time.

Moreover, the deflashing advances substantially simultaneously with the grinding and hence, it is unnecessary to provide a special deflashing step after the grinding, and of course, an exclusive deflashing device is not required. Thus, it is possible to remarkably shorten the machining time for the camshaft 10, thus, to largely provide a reduction in machining cost.

The deflashing brush 40 is formed at a variable diameter with the bent portion 42a formed on each of the wires 42 and hence, can be provided with a simple structure and at a low cost.

It is unnecessary to form a recess for indicating the standard phase in the outer peripheral surface of the camshaft 10 having the large number of cams 10a, 10b --- 10n ground by the above-described process. Therefore, it is possible to simplify the fabrication of a camshaft blank and to provide a

good appearance to the camshaft 10.

A second embodiment of the present invention shown in Fig.8 will now be described.

The second embodiment is different from the previous
5 embodiment in respect of the construction of a deflashing brush
40. More specifically, through-bores 44, 44 are made in a brush
body 41 and arranged circumferentially in a large number of sets
with the adjacent two thereof disposed in a V-shape on opposite
sides of a radius line R to form a pair. Two tip ends of a wire
10 42 bent into a V-shape at its central portion are inserted through
each of the pairs of the through-bores 44, 44 from the side of
an inner periphery of the brush body 41, and the wire 42 is brazed
in each of the through-bores 44. The wire 42 bent into the V-shape
is inclined with respect to the radius line R of the brush body
15 41 in its free state, so that its tip end is located radially
inside the outer peripheral surface of the rotary grindstone
22, as shown by a solid line in Fig.8. However, when the wheel
spindle 21 is brought into a predetermined high-speed rotational
state, the wire 42 is allowed to rise toward the radius line
20 R by a centrifugal force, as shown by a dashed line in Fig.8,
so that its tip end protrudes radially outwards from the outer
peripheral surface of the rotary grindstone 22.

Therefore, the deflashing of each of the cams 10a, 10b
--- 10n of the camshaft 10 can be carried out by the wires 42,
25 42 without being obstructed by the rotary grindstone 22 as in
the previous embodiment by rotating the wheel spindle 21 at a

high speed. According to this modification, each of the wires 42, 42 is not required to be bent into a \wedge -shape at its intermediate portion as in the previous embodiment and hence, the variable diameter-type deflashing brush 40 is further simplified in structure and can be provided at a further low cost.

The arrangement of the other components is similar to that in the previous embodiment and hence, portions or components corresponding to those in the previous embodiment are designated by the same numerals and symbols in Fig.8, and the description of them is omitted.

Although the embodiments of the present invention have been described in detail, it will be understood that various modifications in design may be made without departing from the spirit and scope of the invention defined in claims. For example, the standard phase sensor 35 may be mounted at a place other than the wheel spindle stock 20 such as the table 2. Brush element wires of a deflashing brush 40, which are made of a synthetic resin, may be used in place of the wires 42, 42 made of the metal.